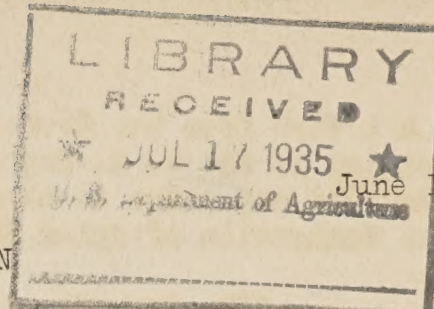


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## DRIED FRUIT FUMIGATION

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## INTRODUCTION

Not more than 7 years ago fumigation of dried fruits was limited to the use of carbon disulphide, both in vacuum and under the usual conditions, and of hydrocyanic acid gas ("cyanide" gas) applied as a rapidly evaporating liquid (hydrocyanic acid) or generated by the pot method. During the last 7 years, however, there has been much activity in the introduction of new fumigants, largely as a result of discoveries made in the course of testing hundreds of chemical compounds by workers in the United States Department of Agriculture.

This systematic search for new and better fumigants has been done by Neifert and Garrison, 2/ by Neifert, Cook, Roark, Tonkin, Back, and Cotton, 3/ and more recently by Back, Cotton, Roark, and Young, who have reported on original work with various formates, ethylene oxide, ethylene dichloride, the use of carbon dioxide as a stimulant in fumigation, etc. As efforts to improve fumigation practice and to adapt new fumigants to dried-fruit work are still in active progress, it is expected that some of the statements made in this circular will need to be revised in the not distant future.

Owing to the numerous variable factors encountered in fumigation practice--tightness of enclosure; density, quantity, and moisture content of material being treated; duration of exposure; temperature (and perhaps humidity); absorption by walls of various construction; and different dosage rates of the gases used--successful and economical fumigation of dried fruits is largely a matter of judgment born of experience. It is often necessary to try different dosage rates and lengths of exposure before deciding upon a routine schedule.

1/ Acknowledgement is made of work in dried fruit fumigation carried on by J. C. Hamlin, W. D. Reed, and A. W. Morrill, Jr., of the Bureau of Entomology and Plant Quarantine. The standard method of measuring the results of fumigation, described in this circular, was developed by Mr. Reed. D. B. Mackie and assistants, of the Department of Agriculture, State of California, are largely to be credited for the development of methods for the fumigation of dried fruits in vacuum fumigators.

2/ Neifert, I. E., and Garrison, G. L. Experiments on the Toxic Action of Certain Gases on Insects, Seeds, and Fungi. U. S. Dept. Agr. Bull. 893, 16 pp. 1920.

3/ Neifert, I. E., Cook, F. C., Roark, R. C., Tonkin, W. H., Back, E. A., and Cotton, R. T. Fumigation Against Grain Weevils with Various Volatile Organic Compounds. U. S. Dept. Agr. Bull. 1313, 40 pp. 1925.



A letter from the Secretary of Agriculture, dated April 28, 1934, states the position of the U. S. Department of Agriculture with respect to the fumigation of foods, and may serve to clarify certain questions which arise in connection with the fumigation of dried fruits. This letter reads in part as follows:

"The Department does not approve or endorse any proprietary fumigant nor does it issue reports that may be used for advertising purposes giving the results of tests on such materials. The composition of a proprietary fumigant is often modified by the manufacturer without changing the label or otherwise warning the consumer. Obviously, the Department cannot recommend a product the composition of which may be changed at any time without notice.

"Fumigation as a means of combating insect pests in foods is a subject in which the Bureau of Entomology is interested from the standpoint of effectiveness in killing insects, the fire and explosion hazard involved, and the effect of the treatment upon the commodity. Although primarily an entomological problem, other bureaus are concerned in its solution and investigations are carried on by the various offices concerned cooperatively or independently. The effects of the fumigant on the treated commodity are determined cooperatively by the interested bureaus of the Department, the particular bureaus cooperating depending upon the nature of the commodity treated. It is not difficult for the Bureau of Entomology to recommend a fumigant as effective in killing insects, provided predetermined favorable conditions always exist, but because effectiveness is influenced by conditions which vary greatly in different manufacturing plants and storages, and because the varying moisture contents of the fumigated foods may render a fumigant safe from the health standpoint for one commodity and dangerous for another, the Department finds it impossible to recommend any fumigant without accompanying reservations which sometimes are more harmful than otherwise to the interests of the manufacturers of a fumigant, particularly from the viewpoint of the uninitiated food manufacturer. There seems to be no fumigant ideal for all food commodities under all conditions of storage, hence judgment based upon experience is necessary in determining the fumigant best suited for each particular problem calling for consideration. While the Department does not recommend fumigants by their proprietary names it can and does give information regarding known chemicals or combinations of chemicals used as fumigants and recommends them as suitable under certain conditions.

"The Bureau of Chemistry and Soils determines the fire and explosion hazard of fumigants and makes studies of diffusion of fumigants within buildings and through various commodities and also studies the sorption of fumigant vapors by a wide variety of materials. This Bureau is also concerned with the question of possible toxicity to man of hydrocyanic acid and other compounds left in foods that have been fumigated.

"The Food and Drug Administration has an interest in the subject of fumigation of foods from two angles. Under the Federal Insecticide Act it is the function of the Administration to institute appropriate action against consignments of insecticides shipped within its jurisdiction which violate any of the provisions of that



law. The Insecticide Act does not authorize the Administration to approve insecticides or their labels. From the standpoint of the Federal Food and Drugs Act the Food and Drug Administration is indirectly concerned about the nature of food fumigants. Under the food law action would lie against consignments of foods shipped within its jurisdiction which may contain such residual quantities of dangerous fumigants as to render the food harmful to health. Because of the important public health considerations involved the Food and Drug Administration cannot consistently take any position with respect to the fumigation of foods except to regard every proposed process as potentially dangerous unless or until it is definitely proved harmless. It cannot be expected to take the position which your letter seems to suggest of at least tacitly approving a fumigation process until it is shown to be harmful."

#### EXPLANATION OF TERMS USED

Bin, fumigable storage.--Storage compartment for bulk fruit, made tight for periodical fumigation.

Boiling point.--The temperature at which, at normal atmospheric pressure, liquids evaporate rapidly with the generation of bubbles of vapor or gas.

Box, fumigation.--Small fumigator provided with a lid.

Concentration.--A saturated atmosphere is one containing all the gas that will evaporate from a liquid surface in a confined space, at a given temperature and pressure. Concentration is expressed as a percentage of the amount that would be present at saturation, or in milligrams per liter, or as percent by volume.

Condensation.--Passage of a vapor into the liquid condition, when the saturation point of a saturated atmosphere is lowered by cooling or by decreased volume.

Cubic centimeter or cc.--Basic unit of volume in metric system of measurement; 1,000 cc. equal 1 liter. There are approximately 473 cc. in a pint.

Diffusion.--Gradual mixing of gases with air, tending to produce a uniform mixture. Penetration of spaces between pieces of packed or bulk fruit is brought about by diffusion.

Disinfectants.--Chemicals used for killing bacteria, yeasts, and molds. These usually are not effective against insects, and, conversely, most commercial fumigants are of little use as disinfectants.

Distribution.--Varying concentration of gas in different parts of an enclosure. It is controlled by method of application, movement of the air, the specific gravity (weight) and temperature of the gas, and by leakage. In some cases wind velocity and uneven heating of walls by the sun affect distribution.



Dosage.--The total amount of fumigant used in a given fumigation job, based on the dosage rate multiplied by the number of times the unit is contained in the space.

Dosage rate.--The amount of fumigant per unit of the total volume of space to be fumigated, usually stated in terms of pounds per 100 or 1,000 cubic feet.

Evaporation rate.--In fumigating with materials that do not boil at ordinary temperatures, the rate of evaporation depends chiefly upon temperature, area of evaporating surface, and air movement. A few fumigants, such as naphthalene, pass from the solid form directly to the gaseous state.

Gas.--A form of matter which is of no definite shape or volume but which tends to expand with any release of pressure. Many elements or chemical compounds are gases at ordinary temperature and pressure, but may be cooled or compressed into liquids or solids. And many substances that are solid or liquid under ordinary conditions will pass into the gaseous state at higher temperatures or reduced pressures.

Hood, fumigation.--A paper-covered frame for setting down over fruit to be fumigated. Used chiefly on ranches for fumigating figs.

House, fumigation.--Separate building near storage plant or on a ranch, for routine fumigation and storage.

Individual-pack fumigation.--Treatment by placing a small quantity of fumigant in each box holding 25 pounds or more of fruit in bulk, the boxes being lined with paper.

Load.--Material placed in an enclosure for fumigation.

Room, fumigation.--Tight compartment within a building, for routine fumigation and temporary storage, usually in boxes.

Sorption.--The entrance of molecules of gases, liquids, or substances in solution into porous solids exposed to them, or the adherence of such molecules to the surfaces of solids. These phenomena are usually called absorption and adsorption.

Vapor.--In technical terms, vapor is evaporated liquid, the liquid being one which does not boil at normal atmospheric temperatures. In fumigation practice vapor is included under the term gas.

Volatility.--The rapidity with which a liquid evaporates at 68° F. is the usual measure of its volatility. This depends chiefly upon the boiling point of the liquid and to some extent upon the concentration of gas immediately above the surface. The quantity of a liquid which will evaporate in an enclosed space filled with air is the same as that which would evaporate if no air were present.



## INSECT STAGES

The insects that attack dried fruits pass through the following 4 stages; Egg, larva, pupa, and adult. The embryo in the egg develops throughout a short incubation period, and the larva emerges usually within 3 or 4 days in warm weather. Even in cool weather, the egg stage lasts not more than about 17 days. In the case of the insects usually fumigated (the raisin moth, Ephestia figulilella Greg.; the Indian-meal moth, Plodia interpunctella Hbn.; the saw-toothed grain beetle, Oryzaephilus surinamensis L.; and the dried fruit beetle, Carpophilus hemipterus L.) there is no evidence that the eggs are harder to kill than the larvae.

The larvae of both moths and beetles ordinarily complete their feeding in from 2 to 5 weeks, but this stage is sometimes much prolonged, especially during cool weather, and may last for several months. In both groups the pupal stage is rarely of more than 4 weeks' duration and is usually much less. The adult life of the moths is brief, seldom longer than 2 or 3 weeks, but the beetles may live for a year or more.

## APPLICATION, PROPERTIES, AND COSTS OF FUMIGANTS

The commonly used fumigants <sup>4/</sup> and the factors in their successful use are here treated in detail. Where prices are given they are approximate and represent quotations received in 1934 prior to September 1.

### Factors in Successful Fumigation

Temperature control.—Since insects and their eggs respire or "breathe" more rapidly at high temperatures, fumigants act upon them more quickly when temperatures are high. Likewise liquid fumigants are more rapidly evaporated, and the molecules of gases are in more rapid motion, with the result that diffusion is accelerated. It is a well-established fact that the difficulty of getting complete kills increases rapidly below 60° F. For all-year-round fumigation, temperature control by steam pipes or other means is essential, as temperatures of 80° to 95° F. are desirable.

Agitation.—Air, a practically constant mixture of several gases, is the standard with which the weights of gases are compared. All fumigants discussed in the later pages produce gases (or vapors) that are heavier than air, with the exception of hydrocyanic acid.<sup>5/</sup> For this reason it appears to be of advantage to have means for mixing gas and air uniformly, to avoid too high a concentration in one part of an enclosure and too low in another. Electric fans serve the purpose. In the case of ethylene oxide, the manufacturers recommend that the motor be outside the fumigation chamber, the shaft of the fan passing through

<sup>4/</sup> Some materials, not discussed here for the reason that their use is considered to be in the experimental stage in dried-fruit fumigation practice, are methyl formate, methyl isobutyl ketone, carbon tetrachloride, ethyl acetate-carbon tetrachloride mixture, and the methyl formate-carbon dioxide mixtures.

<sup>5/</sup> Roark, R. C., and Nelson, O. A. Densities of Mixtures of Air and Various Fumigants. Jour. Econ. Ent., vol. 23, pp. 985-987. 1930.



a stuffing box in the wall.

Ventilation.--Airing of houses can be facilitated by having a door at each end. Fumigation chambers located inside of buildings usually should be provided with exhaust fans to force the used gases out through ducts extending above the roof.

Tightness of enclosures.--It goes without saying that a fumigation chamber should be tight, yet lack of tightness accounts for more failures and waste of fumigants than all other factors combined. As a rule leaks are most common around the doors. Fumigation rooms should be tested occasionally from the inside by closing the doors and looking for light. Small chambers can be tested by burning sulphur in them. When this is done care should be taken to prevent fire.

Just as the boiling of water in a closed vessel produces steam pressure, so the evaporation, either slow or rapid, of a liquid fumigant, whether exposed in a pan or released as an expanding gas from a cylinder under pressure, tends to build up pressure in the fumigation chamber. If the chamber is air tight--which seldom is the case--the rapid introduction of large quantities of a gas may cause the walls to bulge. In practice, leaks in the fumigation chamber usually prevent a large increase in pressure; in very tight enclosures small vents should be left open while the fumigant is being liberated.

Construction materials.--Although little experimental information has been published on the subject of gas-confining building materials, experience has indicated that certain types of construction are satisfactory while others are less advisable. Two thicknesses of tongue-and-groove lumber with roofing paper, sealed with asphaltic cement, between; three-ply veneer; wall board coated with asphaltum; plaster board; and sheet iron are good. Paper on a wood frame is cheap and may be made tight, but is short-lived. For this type of construction a 2-ply building paper filled with cement and vegetable fibers has given good results.

Masonry is porous and should be plastered with a dense plaster, such as Keen's cement. The volume of air that will pass through a well-made brick wall 13 inches thick in the face of a 30-mile-per-hour wind has been measured as 16 cubic feet per hour per square foot. <sup>6/</sup> Proper plastering with gypsum plaster reduced the leakage to 0.92 cubic foot per hour per square foot, but three coats of paint made of white lead and oil permitted the passage of 11.62 cubic feet per hour.

In making chambers tight and in keeping them so it should be borne in mind that they should be tight enough to hold water if they are to hold gas.

Duration of exposure.--The period of fumigation depends on the material to be fumigated (depth of bulk fruit, type of package, etc.), tightness of the enclosure, dosage rate, and temperature. Twelve hours is the time usually recommended, but under favorable conditions 8 hours may be enough. Where

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<sup>6/</sup> Larson, G. L., Nelson, D. W., and Braatz, C. Air Infiltration Through Various Types of Brick Wall Construction. Heating, Piping and Air Conditioning, vol. 1, pp. 585-593, Nov. 1929. (Reprint No. 17, Univ. of Wis. Eng. Expt. Sta.)



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difficulties in getting complete kills are encountered in a tight enclosure and under reasonably good temperature conditions, the dosage rate rather than the duration of exposure should be increased, because the concentrations ordinarily decline steadily, and there is little to be gained by prolonging a fumigation after the gas concentration has become too weak to kill.

Dosage rates.—The dosages given for the different fumigants are for average conditions of tightness and temperature in loaded enclosures. With artificial heat or under hot-weather conditions in tight enclosures the dosage rates can be reduced. It should be mentioned here that dosage rates are not to be reduced when, as is usually the case, the net air space in an enclosure is greatly diminished by the presence of the load of fruit. On the contrary, the increased surface (and sometimes the high moisture content of the fruit) may be expected to bring about sorption, and the moisture tends to dissolve, or to combine chemically with the fumigant, so that the amount available for killing insects is materially lowered. It will be seen, therefore, that a loaded room requires more fumigant than an empty one.

Fire hazards.—In deciding on a fumigant, perhaps the first consideration, next to effectiveness, is the question of inflammability. So far as possible, fumigants which form gas-air mixtures that burn or explode should be avoided. This warning is included here not only because of the danger of burning valuable buildings but because a fire caused by ignition of fumigating gas is likely to result in such rigid restriction by fire-prevention authorities as to interfere seriously with freedom in future operation.

Continuous fumigation.—Several years ago one of the authors of this circular, Charles D. Fisher, developed apparatus for continuous and automatic fumigation of fruit on a belt conveyor in the packing line. The belt was enclosed in a tunnel in which a high concentration of sulphur dioxide was maintained at normal atmospheric pressure, by means of a pressure-reducing valve and electrical heat control of the pressure in a cylinder of liquid sulphur dioxide. Test insects were killed in as short an exposure period as 1 1/2 minutes.

Bulk fruit.—Penetration of fruit in deep piles is difficult, but has been accomplished to depths of 4 or 5 feet. A succession of fumigations, at 3-foot intervals as the bins are filled, is advisable. It is well also, by staggering the containers, to avoid approaching bulk-fruit conditions in piling boxes or bags of fruit. Spaces should be left around the sides and, if possible, beneath the load to facilitate diffusion of gas.

Safety for personnel.—More care than may appear necessary should be taken to guard against injury or death to employees by the materials used. All fumigation gases, even carbon dioxide, are dangerous in high concentrations. Doors to rooms or buildings being fumigated should be locked and placarded with warning signs, but the signs should be removed after danger has passed. Rooms require thorough airing before being entered by workmen. It is always the best plan for fumigators to work in pairs because one of the two may be called upon to rescue the other. Rescue of those overcome with noxious gases should begin by taking the victim to the open air and calling a doctor. In severe cases artificial respiration, by hand or by pulmotor, is necessary. The patient should be in a reclining position and should be kept warm. Stimulants or antidotes should be administered according to such directions as the manufacturer of the fumigant may have made available, or by a physician. The needed remedies should always be on hand. The stock of fumigation chemicals should be carefully labeled and kept in a locked room or preferably in a small detached building.



Checking results of fumigations.--As one plant superintendent has stated, the fact that no complaints have been received is not assurance that fruit is going out free from live infestation. Those who perform routine fumigations can readily determine the results of their work by planting test boxes of insects in the fruit. Small bags of cheesecloth, fitted into perforated pill boxes for protection from crushing, are good for holding the insects. The boxes are buried in the fruit in several locations, and removed for observation afterwards. Larvae of the Indian-meal moth or the raisin moth make satisfactory test insects; they are more difficult to kill than are adults of the saw-toothed grain beetle. A few raisins should be enclosed in the test bags for food. Control bags, not fumigated but otherwise given the same treatment, may be used to indicate whether the fumigated insects die from exposure to the gas or from other causes, such as crushing, parasitization, or exposure to high temperatures. Fumigated insects should be observed for 10 days so that any that revive after apparent death may be recorded.

#### Fumigants Evaporated from Shallow Pans Placed Above the Fruit

##### Carbon disulphide (carbon bisulphide, CS<sub>2</sub>).

Dosage rate..... 15 to 20 pounds per 1,000 cubic feet.

Weight per gallon.. 10.5 pounds (1 lb. = 12.2 fluid oz.)

Boiling point..... 115° F.

Inflammability..... About like gasoline. Fire, frictional electricity, light switches, loose lamp sockets, electric fans, hot objects, and sparks should be guarded against where carbon disulphide is used. The use of this fumigant is severely restricted by fire underwriters.

Toxicity to man.... Has an anesthetic effect; about as toxic as chloroform.

Cost..... 8 to 16 cents per pound.

Remarks..... In cold weather, evaporation should be aided by hanging burlap sacks so that they dip down into the liquid in the pans. When used for vacuum fumigation, carbon disulphide is blanketed with noninflammable carbon dioxide (carbonic acid gas) or with nitrogen, for reduction of fire hazard.

##### Ethylene dichloride-carbon tetrachloride mixture, 3 parts to 1.

Dosage rate..... 15 to 20 pounds per 1,000 cubic feet.

Weight per gallon 11.2 pounds (1 lb. = 11.4 fluid oz.)

Boiling points..... Ethylene dichloride 182.6° F.

Carbon tetrachloride 170.6° F.

Inflammability..... None.



Toxicity to man... Has an anesthetic effect, like that of chloroform.

Cost..... 7 to 15 1/2 cents per pound.

Remarks..... Artificial heat or wicks consisting of gunny sacks are necessary for effective evaporation in cool weather.

Ethylene oxide (C<sub>2</sub>H<sub>4</sub>O).

Dosage rate..... 2 pounds per 1,000 cubic feet.

Weight per gallon 7.4 pounds (1 lb. = 17.3 fluid oz.)

Boiling point.... 50.9° F.

Inflammability... None when uniform gas-air mixtures contain less than 3.67 pounds ethylene oxide per 1,000 cubic feet. During evaporation, however, concentrations within the flammable range are doubtless reached near the surface of the liquid, and there is consequently some fire hazard. (See ethylene oxide-carbon dioxide mixture.)

Toxicity to man... Not highly toxic in low concentrations.

Cost..... 80 cents to \$1 per pound.

Remarks..... This fumigant requires tight enclosures, favorable temperatures, and preferably a fan for circulation. It has a strong affinity for moisture; therefore, during fumigation its concentration decreases markedly. When warmer than its boiling point, the material may be sprayed into the air from cylinders, under pressure of its own gas.

Chloropicrin (Tear gas; chlorpicrin, nitro-chloroform, nitrotrichloromethane) (CCl<sub>3</sub>NO<sub>2</sub>).

Dosage rate..... 1 pound per 1,000 cubic feet.

Weight per gallon. 13.75 pounds (1 lb. = 9.3 fluid oz.)

Boiling point..... 233.6°F.

Inflammability.... None.

Toxicity to man... Irritating to eyes and respiratory surfaces. This warning quality serves to prevent entry into high concentrations,, which are dangerously toxic.

Cost..... 80 cents to \$1.30 per pound.



Remarks..... In cold weather the liquid may be dispensed as a spray from small pressure cylinders. If folded burlap sacks are laid in the pans before chloropicrin is poured in, evaporation is improved. The gas is slow to clear away from fumigated material.

Fumigants Released as Gases From Liquids Under Pressure

Hydrocyanic acid ("liquid cyanide", prussic acid) (HCN).

Dosage rate..... 20 ounces per 1,000 cubic feet.

Weight per gallon. 5.8 pounds.

Boiling point..... 77° F.

Inflammability.... Dilute gas is nonexplosive; concentrated gas (6 percent and over by volume in air) is explosive, but this concentration is not reached until about 66 ounces per 1,000 cubic feet is present. Liquid hydrocyanic acid will burn.

Toxicity to man... A highly toxic "chemical asphyxiant."

Cost..... 85 cents to \$1.30 per pound.

Remarks..... After prolonged storage in cylinders, chemical decomposition of the acid may take place, with increase in pressure which may result in the bursting of the cylinder. Cylinders should be returned to the manufacturer of the acid after 90 days. This fumigant is sold also absorbed in paper disks, in which form the liquid costs \$1.20 to \$1.30 per pound. When the disks are used, the operator should wear a mask.

Ethylene oxide-carbon dioxide mixture, 1 part to 9.

Dosage rate..... 10 to 15 pounds per 1,000 cubic feet.

Boiling points..... Ethylene oxide 50.9° F.

Carbon dioxide-112° F.

Inflammability..... None.

Toxicity to man.... Relatively nontoxic.

Cost..... 19 to 21 cents per pound.

Remarks..... This mixture is said to be effective for use in vacuum fumigators. The substitution of solid carbon dioxide for the gaseous carbon dioxide produces a slowly volatile, slushy fumigant. The carbon dioxide in the mixture serves a twofold purpose: It eliminates all fire hazard, and it stimulates the respiration of insects.



Sulphur dioxide, liquid (liquid SO<sub>2</sub>).

Dosage rate..... 7 pounds per 1,000 cubic feet.

Weight per gallon. 12 pounds.

Boiling point..... 14° F.

Inflammability.... None.

Toxicity to man... Irritates eyes and respiratory surfaces.

Cost..... 8 to 12 cents per pound.

Remarks..... This is the heaviest of the fumigants considered here, air saturated with sulphur dioxide vapor having a specific gravity twice that of air alone. Dried fruit treated with sulphur dioxide, for any purpose, is required to be labeled "prepared with sulphur dioxide" if entered in interstate commerce.

Fumigants Generated Where Used

Hydrocyanic acid gas, pot method (HCN).

Dosage rate (1-1 1/2-2 formula) 7/..

40 ounces sodium cyanide, 60 fluid ounces sulphuric acid, and 80 fluid ounces water per 1,000 cubic feet.

Inflammability..... None in case of dilute gas.

Toxicity to man.... Highly toxic.

Cost..... 1-ounce eggs of sodium cyanide, 18 1/2 to 28 cents per pound. 1/2-ounce egg-shaped pieces of sodium cyanide, 18 1/2 cents per pound. Sulphuric acid, commercial, 1 1/2 to 10 cents per pound; weight 15.3 pounds per gallon. A fluid ounce is a measure of volume, not weight, and is equal to one-sixteenth pint.

Remarks..... The water is placed in a crock or other suitable acid-resisting container; the acid is added slowly, and the sodium cyanide, in a paper bag, is dropped in last, after which the operator should leave the building without delay. Sodium cyanide is a deadly and very rapid poison, and the sulphuric acid is capable of causing severe burns. The residue is poisonous and should be buried. Since the acid residue corrodes iron, it should not be disposed of by pouring it into iron sewer connections. Additional instructions and

7/ If trouble is experienced in emptying the residue after fumigation, a less concentrated residue may be produced by the use of the ingredients in the proportions of 1-1 1/2-3.



cautions are to be found in Farmers' Bulletin 1670, 8/ which should be studied by all persons intending to use this fumigant.

Hydrocyanic acid gas, calcium cyanide method (HCN).

Dosage rate..... 100 ounces per 1,000 cubic feet.

Inflammability..... None in case of dilute gas.

Toxicity to man..... Highly toxic.

Cost..... 16 to 75 cents per pound.

Remarks..... The reaction is produced by chemical combination of water vapor with the finely divided calcium cyanide. The dust is usually sprinkled on moistened paper. Some residual hydrocyanic acid remains for a time in the spent powder, which should be disposed of carefully. The above directions call for the use of a commercial material containing about 25 percent of hydrocyanic acid. A more concentrated product, containing about 50 percent hydrocyanic acid, sells for \$1.03 to \$1.48 per pound. A mask should be worn when applying the higher-strength material.

Sulphur dioxide, produced by burning sulphur (SO<sub>2</sub>).

Dosage rate..... 10 to 15 pounds sulphur per 1,000 cubic feet.

Inflammability..... Sulphur dioxide does not burn, but the burning sulphur presents a fire hazard.

Toxicity to man..... Irritates eyes and respiratory surfaces.

Cost of sulphur..... 4 cents per pound.

Remarks..... Each pound of sulphur burned theoretically produces 2 pounds of sulphur dioxide. Fumigation by this method requires that a small supply of air be admitted to the chamber in order to support combustion of the burning sulphur. Dried fruit treated with sulphur dioxide, for any purpose, is required to be labeled "prepared with sulphur dioxide", if entered in interstate commerce. The heat generated by the burning sulphur is an advantage. This is the cheapest fumigant known.

Individual-Pack Fumigation in Packing Line

Ethyl formate.

Dosage rate..... 5 to 9 cc. per 25-pound box.

8/ Back, E. A. and Cotton, R. T. Hydrocyanic Acid Gas As a Fumigant for Destroying Household Insects. U. S. Dept. Agr. Farmers' Bull. 1670, 20 pp., illus. 1932.



Weight per gallon. 7.7 pounds.

Number of cc. per pound. 492 (3,785 cc. per gal.)

Boiling point..... 130° F.

Inflammability..... Explosive range 2.5 percent by volume (about 5 lbs. per 1,000 cu. ft.) to 14.0 percent by volume.

Toxicity to man..... Mildly anesthetic; irritating to respiratory membranes.

Cost..... 28 to 35 cents per pound.

Remarks..... Since ethyl formate is sprinkled onto the paper liner before the fruit is introduced and comes into direct contact with some of the fruit, it is important to use only a pure grade.

In addition to ethyl formate, at present the standard for individual-pack fumigation, the writers have found that ethylene oxide-solid carbon dioxide mixtures can be used for individual-pack fumigation; however, there is considerable loss of the refrigerant during storage. Experiments with other fumigants are under way.

#### SUGGESTIONS FOR CHOICE OF FUMIGANTS

Rooms, fumigable bins, and small detached houses at packing houses and storage plants.—Any of the fumigants about which details have been given and which does not present an objectionable degree of fire hazard may be used. The necessity for proper labeling of fruit treated with sulphur dioxide needs to be considered as well as the possibility of the fumigation residues referred to in the letter of the Secretary of Agriculture which was quoted. Chloropicrin and sulphur dioxide should not be used where traces of these gases would interfere with workers. Ethyl formate should be confined to individual-pack fumigation.

Open piles, under fabric covers.—The same fumigants as above may be used, except that ethylene oxide and the ethylene oxide-carbon dioxide mixture are not advisable because of leakage. This type of fumigation should be regarded only as an emergency operation. Best results probably can be expected only with rubberized fabric. Waterproofed canvas cannot always be depended upon to assure the prolonged "soaking" in high concentrations of gas that is needed for penetration and killing of insects in dried fruit. The manufacturers state that the ethylene dichloride-carbon tetrachloride mixture may be sprinkled directly on the fruit just before the pile is covered.

Plant fumigation.—When this is thought necessary, a commercial fumigator should be hired to seal the building and fumigate it with hydrocyanic-acid gas.

Individual-pack fumigation.—Ethyl formate should be used.

Vacuum fumigation.—Carbon disulphide blanketed with carbon dioxide is recommended. Even heavy dosage rates may fail to kill in cold weather. For effective work in winter, vacuum fumigators probably should be heated.



Refrigerator cars.--These are usually treated with hydrocyanic-acid gas, ethylene oxide, or chloropicrin. These cars are of uncertain tightness, and some cannot be successfully fumigated. (An extended survey made in 1930 by workers of the dried-fruit insect laboratory showed that at that time cars placed for loading with dried fruit at one packing plant in Fresno had been so well cleaned that there was no need for fumigation before loading. Fumigation of empty cars, however, is sometimes necessary.)

Box cars.--Fumigation of dried fruit in box cars is not advisable because of leakage.

Separate houses, boxes, and hoods, on ranches.--Any of the fumigants except ethyl formate may be used. Hydrocyanic acid should preferably be applied by the calcium cyanide method, using the lower-strength type. This is somewhat more expensive but safer and quicker than the pot method. Liquid hydrocyanic acid is not well adapted for ranch use.

Rooms and bins in farm buildings.--Inflammable materials such as carbon disulphide are not advisable because of fire risk and fire insurance considerations.

Box shook, carton stock, labels, paper liners, and burlap bags.--These materials sometimes become infested, chiefly by insects seeking pupation quarters. When placed in a fumigation chamber, they should be arranged as loosely as possible. Any gas may be used except sulphur dioxide, which has a bleaching effect.

#### LIST OF DEALERS IN FUMIGANTS IN CALIFORNIA

The following list is believed to include nearly all of the California firms that handle fumigants in large quantities. Most of them also sell small orders. No attempt has been made to include firms which do a general retail business in agricultural chemicals and farm supplies. This list is given merely for the convenience of the reader, and does not imply a recommendation of any particular company, or of any special brand of material.

American Cyanamid & Chemical Corp., Sacramento and Battery Sts., San Francisco, Calif. Calcium cyanide, sodium cyanide. At Azusa, Calif., liquid hydrocyanic acid, calcium cyanide, and sodium cyanide.

Ansul Chemical Co. of California, Modesto, Calif. Chloropicrin.

Braun-Knecht-Heimann Co., 576-584 Mission St., San Francisco, Calif. Ethyl formate, sodium cyanide, sulphuric acid, ethylene dichloride-carbon tetrachloride mixture, carbon disulphide, sulphur dioxide.

California Spray-Chemical Corp., Fresno, Berkeley, Sacramento, and other cities. Calcium cyanide and similar fumigants.

Carbide and Carbon Chemicals Corp., 114 Sansome St., San Francisco; and 1310 Santee St., Los Angeles, Calif. Ethylene dichloride-carbon tetrachloride mixture, ethyl formate, ethylene oxide, ethylene oxide-carbon dioxide mixture, and similar fumigants.



Coffin-Redington C

Coffin-Redington Co., 401 Mission St., San Francisco, Calif.  
Calcium cyanide.

E. I. du Pont de Nemours & Co., R. & H. Chemicals Dept.,  
601 Third St., San Francisco, and El Monte, Calif. Sodium cyanide and  
other cyanides.

Esotoo Fumigation Co., Ltd., 3120 E. Tulare St., Fresno; and  
465 California St., San Francisco, Calif. Liquid sulphur dioxide.

John. F. Leinen Chemical Co., 1337 Mission St., San Francisco,  
Calif. Calcium cyanide.

McKesson-Langley-Michaels Co., 50 1st St., San Francisco, Calif.  
Calcium cyanide and other cyanides. At 442-464 P St., Fresno, Calif.,  
sodium cyanide, carbon disulphide, sulphuric acid, ethylene dichloride-  
carbon tetrachloride mixture, hydrocyanic acid in paper disks.

Wheeler, Reynolds & Stauffer, 624-638 California St., San Francisco,  
Calif. Carbon disulphide.



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